<Articles><Geomorphology>Calibration of rock-surface moisture content using an infrared optical moisture metre : the relationship between absorbance intensity and moisture content of several types of rock

著者	Matsukura Yukinori
雑誌名	Annual report of the Institute of Geoscience, the University of Tsukuba
号	27
ページ	7-10
発行年	2001-12-25
URL	http://hdl.handle.net/2241/7373

Ann. Rep., Inst. Geosci., Univ. Tsukuba, no. 27, pp. 7-10, Dec. 25, 2001.

Calibration of rock-surface moisture content using an infrared optical moisture metre: the relationship between absorbance intensity and moisture content of several types of rock

Yukinori Matsukura

Introduction

Matsukura and Takahashi (1999) have examined the possibility of in situ rapid, non-destructive measuring of rock moisture content using an infrared optical moisture metre. A laboratory test was carried out using Aoshima sandstone used for a masonry bridge pier. The results indicated a linear relation between the absorbance intensity of infrared rays (X) and the moisture content (w) of rock sample surfaces. Following this study, we gathered calibration data between absorbance intensity and the moisture content of several types of rock. The present paper describes the compiled data.

Absorbance-moisture calibration for Aoshima sandstone

The apparatus used in the present study was a convenient type of *infrared optical moisture metre* (JE100) manufactured by the Japanese Tobacco Engineering Company. The fundamentals of the methodology of measurement using this particular apparatus have been explained by Matsukura and Takahashi (1999) who first performed the calibration using Aoshima sandstone (Sample Nos.1 to 7 shown in Table 1). Preliminary measurements suggest that the difference in moisture content between rock surface and interior decreases with a decrease in sample thickness; thinner samples were shown to dry more quickly. Therefore, Matsukura and Takahashi (1999) quantitatively examined the effects of sample thickness on X-w relationships. Five discs, 6.4 cm in diameter, with a variety of thicknesses (0.3, 0.5, 1.0, 2.0, and 3.0 cm) were prepared. The test procedure was as follows: (1)

Table 1. Results of calibration of rock-surface moisture content; X-value is the absorbance intensity of infrared rays under conditions of saturation, w is the saturated moisture content, and α is the proportional coefficient in both data.

	Rock	Location	Unit weight (gf/cm^3)	Porosity (%)	w (%)	X	α	Reference
1	Sandstone	Aoshima: Miyazaki	2.36	8.86	2.42	0.138	17.54	Matsukura and Takahashi, 1999
2	Sandstone	Aoshima I: Miyazaki	2.41	7.56	3.275	0.1671	19.6	*ditto*
3	Sandstone	Aoshima II: Miyazaki	2.43	6.93	2.766	0.1568	17.64	*ditto*
4	Sandstone	Aoshima III: Miyazaki	2.47	5.68	2.068	0.1186	17.44	*ditto*
5	Sandstone	Aoshima IV: Miyazaki	2.46	7.27	2.471	0.144	17.16	*ditto*
6	Sandstone	Aoshima V: Miyazaki	2.32	9.83	4.028	0.2191	18.38	*ditto*
7	Sandstone	Aoshima VI: Miyazaki	2.33	9.29	3.587	0.2088	17.18	*ditto*
8	Tuff breccia	Furosan; Oku-Matsushima	0.967	55.1	51.88	1.1537	44.97	Matsukura *et al*., 1999
9	Tuff	Miyato Island; Oku-Matsushima	1.407	28.5	20.78	0.9005	23.08	*ditto*
10	Conglomerate	Hikiiwa (GS1): Tanabe-shi	2.13	20.05	4.74	0.7054	6.72	Mizuno and Matsukura, 1999
11	Sandstone	Hikiiwa (S3): Tanabe-shi	2.15	19.91	8.775	0.6859	12.76	*ditto*
12	Sandstone	Hikiiwa (S4): Tanabe-shi	2.19	16.28	9.74	0.7135	13.65	*ditto*
13	Sandstone	Hikiiwa (S6): Tanabe-shi	1.91	27.27	9.505	0.8757	10.85	*ditto*
14	Sandstone	Hikiiwa (S7): Tanabe-shi	2.05	22.44	5.88	0.661	8.9	*ditto*
15	Alt. Sd & Mud*	Hikiiwa (SM2): Tanabe-shi	2.25	18.24	4.8	0.5	9.6	*ditto*
16	Conglomerate	Hikiiwa (GS6): Tanabe-shi	2.3	12.63	5.007	0.8599	5.82	*ditto*
17	Sandstone	Hikiiwa (S9): Tanabe-shi	2	24.54	6.944	0.6959	9.98	*ditto*
18	Sandstone	Hikiiwa (S10L): Tanabe-shi	2.37	10.98	5.291	0.9324	5.67	*ditto*
19	Sandstone	Hikiiwa (S11): Tanabe-shi	2.07	21.91	7.409	0.6849	10.82	*ditto*
20	Conglomerate	Hikiiwa (GS10): Tanabe-shi	2.21	16.94	4.506	0.9003	5	*ditto*
21	Sandstone	Hikiiwa (S14): Tanabe-shi	2.17	18.42	7.05	0.6805	10.36	*ditto*
22	Hyaloclastite	Toyohama: Hokkaido	2.12	22.6	6.022	0.599	10.05	Akasaki, 2000
23	Hyaloclastite	Wakkake: Hokkaido	2.4	no data	3.8	0.19	20	*ditto*
24	Tuff (Oya-ishi)	Oya: Tochigi	no data	no data	21.66	0.8206	24.6	Yamada, 2000
25	Tuff (Oya-ishi)	Oya: Tochigi	1.45	41.32	22.19	0.9581	23.16	Matsukua, unpublished
26	Granite	Taebo granite: Korea	2.51	4.56	1.56	0.6162	2.53	Matsukura and Tanaka, 2000
27	Granite (fine grain)	Makabe, Kabasan: Ibaraki	no data	no data	0.19	0.2362	0.804	Matsukura *et al*., 2001
28	Granite	Inada: Ibaraki	2.63	0.908	0.405	0.4461	0.908	Matsukura, unpublished
29	Granite	Obara: Aichi	no data	no data	0.595	0.3634	1.637	*ditto*
30	Granite	Abukuma: Fukushima	no data	no data	1.112	0.6723	1.669	*ditto*
31	Brick	Shimoren; Nogi-machi	1.779	no data	16.82	0.487	34.53	*ditto*

Alt. Sd & Mud*: Alternation of sandstone and mudstone

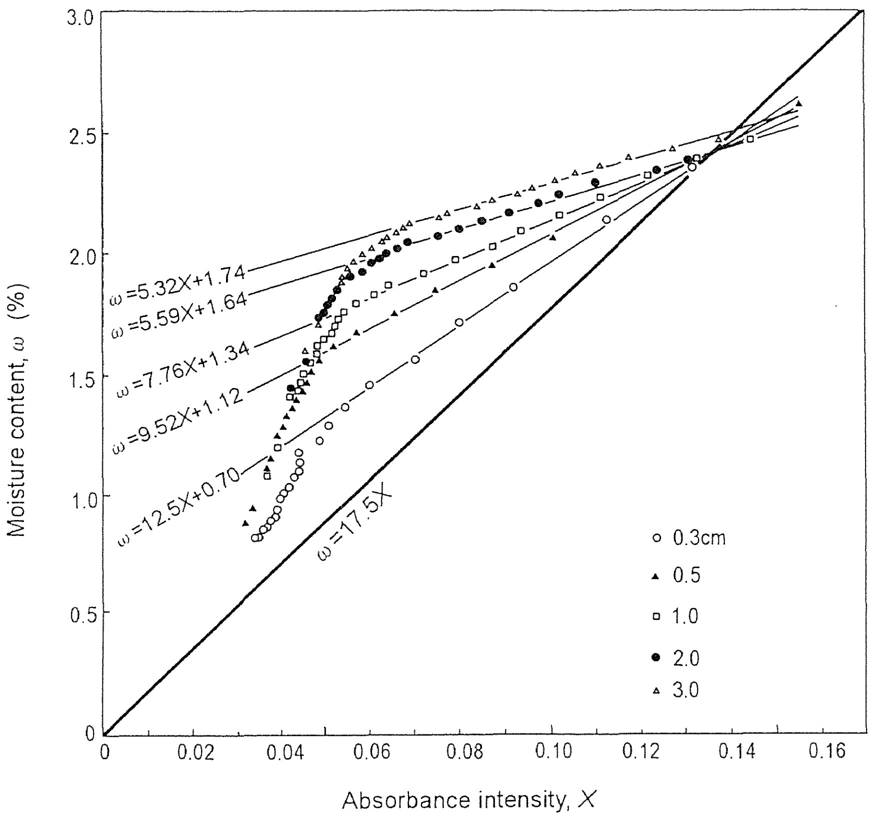

Fig. 1. The relationships between absorbance (X-value) and moisture content (w) for a variety of disc thicknesses.

the samples were submerged in water for 10 days; (2) each sample was removed from the water and its surface was wiped with a damp cloth, weighed (W_w), and then was subjected to X-value measurement on an appointed plane surface of the sample; (3) the sample was then left to dry at both planar surfaces of each disc, which was exposed to air to dry under conditions at room temperature; (4) during this drying process, W_w- and X-values were repeatedly measured at appropriate time intervals; (5) X-values were obtained for each sample by averaging the measurements obtained from both surfaces. Moisture content (w) for each time point was calculated using the ratio: $(W_w - W_d)/ W_d$, where W_d was the dry weight of the test piece after oven drying for 48 hours at 110 °C.

The results in Fig. 1 show X-values of 0.15 to 0.16 at the maximum moisture content (*i.e.*, under saturated conditions) of about 2.3 to 2.5%. The figure indicates that data plots for each disc were approximated by two linear lines with a break point. However, the slope of the lines was different according to disc thickness. The slope of the lines before the break point increased with decreasing thickness; as the sample thickness decreased the lines approached a straight line (depicted by a solid bold line).

After 9 hours of air-drying, the moisture content of a 0.3-cm thick disc was 0.8 % and it was 1.6 % for a 3.0-cm disc. After oven drying at 110 °C for 24 hours followed by cooling at room temperature (25 °C) for 5 minutes, the samples showed an X-value of approximately null (range: 0.0005-0.0050). It is suggested that such extremely small values of X are due to the fact that vapor steam was attached to the disc surface during the cooling process.

A proportional coefficient along the regression lines and a vertical-axis intercept are plotted against the disc thickness in Figs. 2A and 2B, respectively. Regression lines for the upper part of the breaking point are given for each thickness of the samples in Fig. 1. Since both disc sides in the present test were exposed to air to dry, the value on the horizontal axis in Fig. 2 is taken as one half of the thickness for each disc. Extrapolation of the curve connecting each data point shows that the proportional coefficient (α-value) was 17.5 and the intercept was null when the thickness was null, *i.e.*, on the rock surface. This finding suggests that the w-value is simply proportional to the X-value, as follows:

$$w = 17.5\,X \qquad \text{(1)}$$

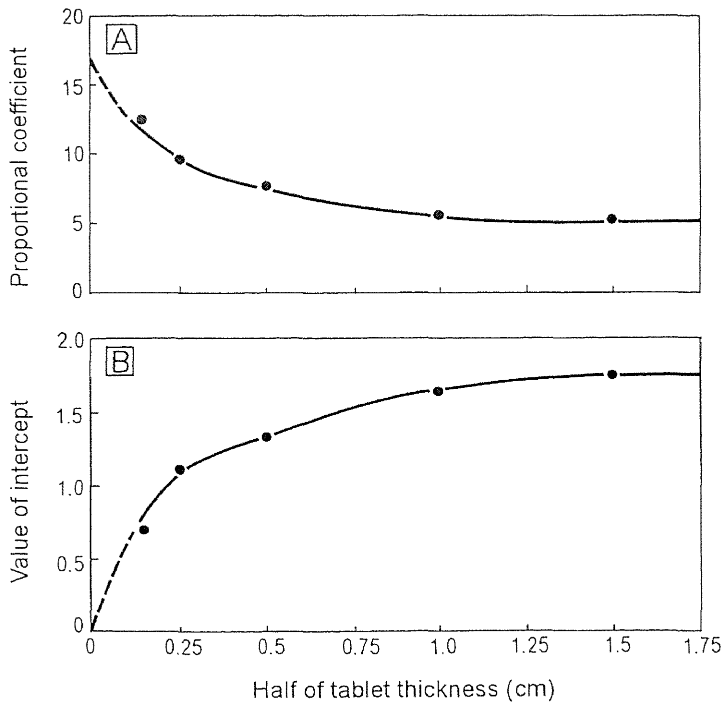

Fig. 2. The relationships between the thickness of the discs and the proportional coefficient (A) and the value of the intercept to the vertical-axis (B).

This relation shows the line connecting the origin and the intersecting point for five regression lines, *i.e.*, the point at which the saturated condition is w = 2.42 % and X = 0.138 (Fig. 1).

Taken together, the above tests suggest that (1) the segmentation with a break point in the X-w relationship during the drying process is derived from the inhomogeneity of the moisture content in the sample, and (2) only the data regarding saturated and perfect drying of the whole sample indicate the true relationship between the X- and w-values.

Coarse sandstone blocks of Aoshima formation have a variety of properties (Table 1). For this study, five samples (Nos. 2 to 7) with different porosities were prepared. Each was cut in about 1-cm thick disc from different sandstone blocks. The samples had a different saturated moisture contents ranging from 2.1 to 4.1%. Using these samples, X-values under saturated conditions were obtained. The results showed that (1) samples with a higher saturated moisture content had larger X-values and (2) the α-value fell within the small range from 17.18 to 19.6 (average, 18.0). The second finding revealed that the equation w = 18.0 X enabled immediate conversion from X-value to moisture content in the case of Aoshima coarse sandstone.

X-values in various rocks: Discussion

The α-value of Aoshima sandstone averaged out to be 18.0. In order to obtain the α-value of other kinds of rock, a total of 31 samples were selected: 25 sedimentary rocks, 5 granites, and one brick (Table 1). Using these samples, X-values under conditions of saturation were obtained and the proportional coefficient (α-value) in both data sets were calculated, as shown in Table 1. The α-value ranged widely from 0.908 (No. 28, n = 0.9%) to 44.97 (No. 8, n = 55.1%). Some of the data, including these two examples, show that the rocks with low porosity such as granite (Nos. 26 through 30) have small α-values, while the rocks of high porosity such as tuff and brick (Sample Nos. 8, 9, 24, 25, and 31) have large α-values. However, the α-values of all samples were weakly correlated with porosity: the correlation coefficient was 0.597. Therefore, the α-value could not be estimated from the porosity, suggesting that α-values may be controlled not only by porosity but also by other rock properties such as colour and roughness of the surface, grain size of the mineral, and mineral composition.

Although a laboratory calibration using the same kinds of rock under fully saturated conditions is needed, the present apparatus has several advantages, as follows: (1) nondestructive measurements can be carried out within a few seconds, and (2) the instrument, being light and convenient, can be used not only in the laboratory but also in the field. This instrument is useful for monitoring spatial and temporal changes in rock-surface moisture content, which is an important factor in the evaluation of the intensity of mechanical weathering occurring at rock surfaces.

Acknowledgements

This study was financially supported by the Science Research Fund of the Ministry of Education, Science and Culture (C-07680191, Principal investigator: K. Takahashi), and by funds from the University of Tsukuba Research Project.

References

Akasaki, K. (2000): Unpublished BS Thesis, Institute of Geoscience, University of Tsukuba, 94p. (*in Japanese with English abstract*).

Matsukura, Y. and Takahashi, K. (1999): *Engng. Geol.*, **55**, 113-120.

Matsukura, Y., Takaya, Y. and Oguchi, C. T. (2001): *Bull. Terrest. Environm. Res. Center*, **2**, in press (*in Japanese*)

Matsukura, Y. and Tanaka, Y. (2000): *Geogr. Annaler*, **82A**, 59-67.

Matsukura, Y., Waragai, T. and Oguchi, C. T. (1999): *Ann. Rep., Inst. Geosci., Univ. Tsukuba,* **25**, 19-22.

Mizuno, K. and Matsukura, Y. (1999): *Trans. Japan. Geomorph. Union*, **20**, 571-588. (*in Japanese with English abstract*).

Yamada, T. (2000): Unpublished BS Thesis, Institute of Geoscience, University of Tsukuba, 73p. (*in Japanese with English abstract*).